28 December 2007

NPOESS Preparatory Project
Advanced Technology Microwave Sounder (ATMS)
Postlaunch Calibration and Validation Plan

(publicly accessible version)

National Aeronautics and Space Administration (NASA)
Goddard Space Flight Center (GSFC)
Greenbelt, Maryland 20771

Submitted by:

NPP ATMS Science Team

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Purpose

This document contains plans for post-launch calibration and validation checkout of the Advanced Technology Microwave Sounder (ATMS). The calibration and validation checkout described here shall be performed during the activation, checkout phase and operational phase of the National Polar-orbiting Environmental Satellite System (NPOESS) Preparatory Project (NPP) mission. Note that most of the ATMS instrument information are adopted from Northrop Grumman Report 13676.

1. ATMS DESCRIPTION

1.1 ATMS Hardware Overview

The ATMS is a 22-channel mm-wave radiometer, shown in Figure 1-1. The ATMS will measure upwelling radiances in six frequency bands centered at 23 GHz, 31 GHz, 50-58 GHz, 89 GHz, 166 GHz, and 183 GHz. The ATMS is a total-power radiometer, with “through-the-antenna” radiometric calibration. Radiometric data is collected by a pair of antenna apertures, scanned by rotating flat-plate reflectors. Scanning is performed cross-track to the satellite motion from sun to anti-sun, using the "integrate-while-scan" type data collection. The scan period is 8/3 second, synchronized to the Cross-track Infrared Sounder (CrIS) using a spacecraft-provided scan synchronization pulse.

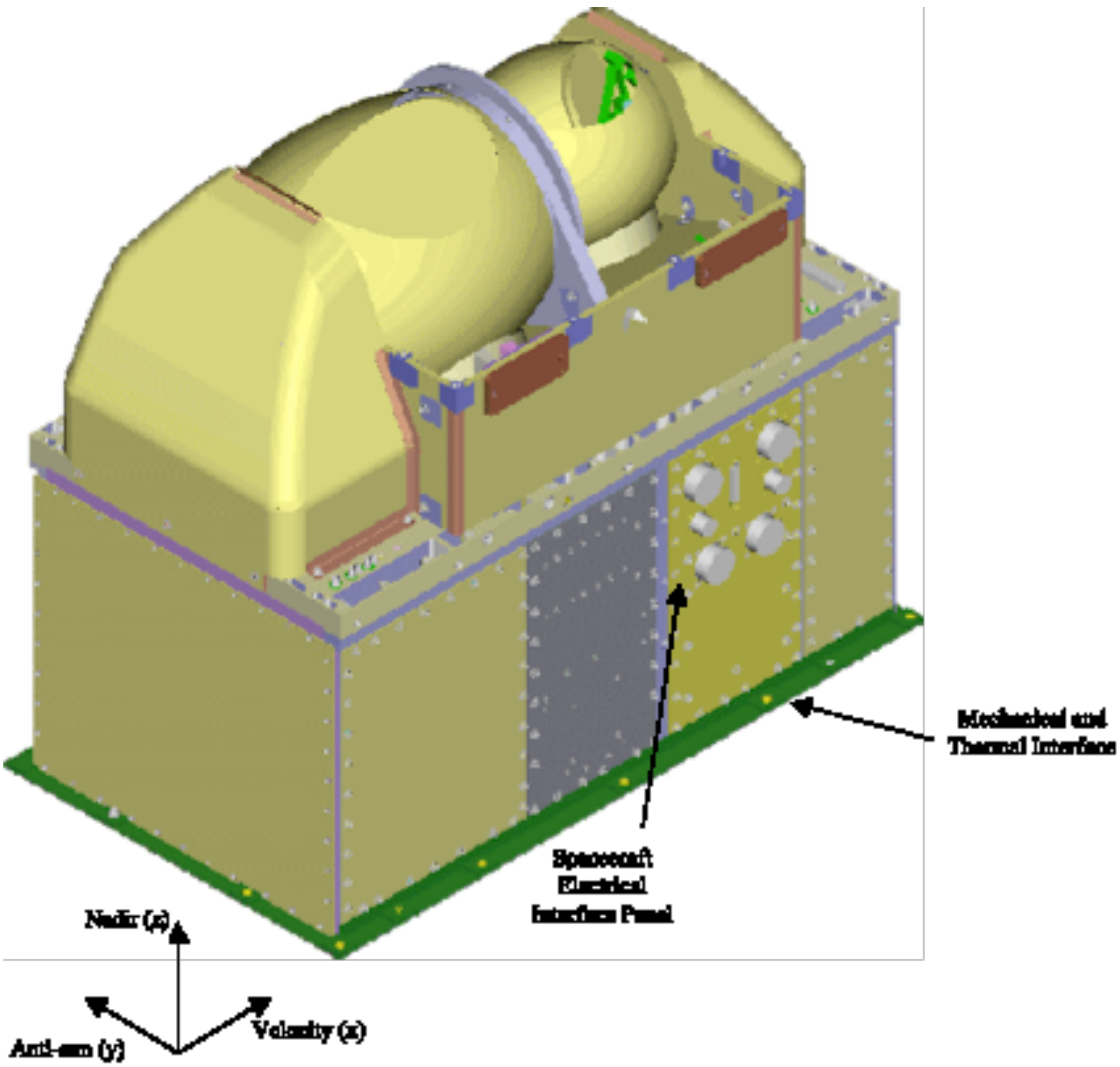

Figure 1-1 ATMS Instrument

1.2 Scan Profiles

The ATMS has four selectable Scan Profiles. The difference between the Scan profiles is the start angle of the cold calibration positions. Figure 1-2 depicts the beam position geometry. Table 1-1 shows the start angle for each of the cold calibration positions.

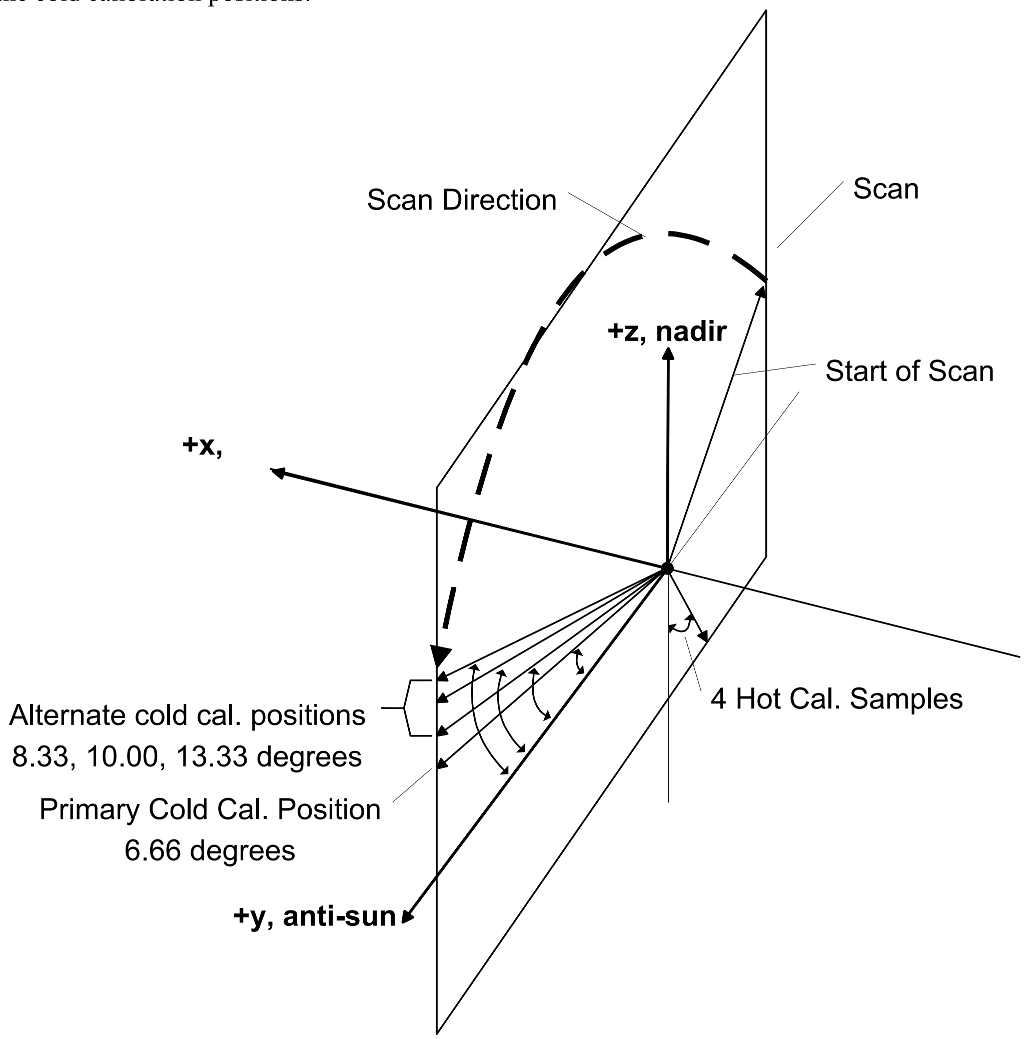

Figure 1-2 Beam Position Geometry

Scan Profile	Cold Cal Angle
1	6.66°
2	8.33°
3	10.00°
4	13.33°

Table 1-1 Cold Calibration Angle Start Positions

1.3 Science Objectives

Mission data obtained from the ATMS and the CrIS will be used to produce three of the NPOESS Environmental Data Records (EDRs):

- Atmospheric Temperature Profiles
- Atmospheric Moisture Profiles
- Atmospheric Pressure Profiles

The primary roles of ATMS are to obtain data during overcast conditions, to provide corrections for cloud effects in partly cloudy conditions, and to provide a "first-guess" for iterative physical retrievals. The ATMS data will also support generation of the following EDRs:

- Cloud liquid water content
- Precipitation rate
- Snow cover

2. ON-ORBIT PERFORMANCE EVALUATION

The procedures for on-orbit instrument checkout and the functional evaluations described below may be performed over a period of several orbits, in order to cover the full range of thermal and EMI environments.

2.1 Passive Telemetry Assessment

The Passive Analog Temperature (PAT) telemetry points shall be monitored prior to initial instrument turn-on to ensure key temperatures are within allowable operational limits. The temperatures should be within Yellow (safe) limits prior to instrument turn-on. These temperatures are monitored by the Spacecraft and reported in the Spacecraft Telemetry.

2.2 Health and Status Telemetry

After the Instrument Activation is completed, verify that all the telemetry items are within the Yellow Limits. Depending on the spacecraft interface temperature the PRT temperatures could take several orbits to reach their operating values.

2.3 Engineering (HotCal) Telemetry

After the Instrument Activation is completed, verify that the hot calibration load temperatures, derived from the 4-wire PRT data in the Engineering HotCal Temperatures Data Packets (APID=212_{16}), are within the expected operational range of 260 K to 330 K, and that all the PRTs within each load are in agreement within ± 1°C.

Determine if there are any PRT outliers (w.r.t. T/V good data), which could indicate a bad PRT or a thermal gradient across the calibration target, and identify PRT temperature difference for each warm load unit. In this test, we need to have each black body PRT temperature, in normal scan mode, for 24 hours. Then determine the minimum and maximum PRT temperatures for each warm load unit for each scan. Compare the PRT temperature difference (max – min) for each warm load unit. Identify any individual PRTs that are out of bounds, using T/V data as a benchmark. Also, we should analyze PRTs during thermal stress, such as while passing over Antarctica during winter (June). However, it would also be of value to do this test at other times.

2.4 Scan Angles

Compare the scan angle readouts in the Science Data Packets (APID=210_{16}) with the specified scan table. Verify that the errors within the Earth-View sector are no greater than ± 0.035 degrees, and that the calibration samples are within the specified sector ± 2.25 degrees. Verify also the following items: (1) The scan angles in all scan positions are denoted correctly in the RDR packets; (2) The scan angles in all scan positions are repeatable; (3) The motor encoder position readings do not drift appreciably for any of the scan positions. This shall be done both for all operational scan profiles. All data required is available while the instrument is in operational mode.

2.5 Dynamic Range and Gain Analysis

The purpose of this evaluation is to verify that the radiometric counts in the Science Packet (APID=210_{16}) do not exceed the specified maximum allowable for the instrument Analog-to-Digital conversion. The ATMS shall be in the operational mode for this evaluation. The Hot Calibration counts (APID=212_{16}) (beam position 102 or 103) shall be converted to an equivalent value at 300 K brightness temperature, using the following equation:

$$C_{300} = C_{Hi} + G_i(300 - T_H),$$

where C_{Hi} is the count value for the ith scan, G_i is the channel gain, and T_H is the physical temperature of the target. A running average of this derived counts value shall be computed, over 100 scans. This data should be accumulated for at least one orbit. The maximum allowable average value, for any channel, is 45,150 counts.

Determine if the radiometric gain and radiometric output are as expected. These analyses should be performed on T/V measurements as well as on-orbit data, and the results should be compared. First, T/V data should be analyzed to determine radiometric gain and its dependence on instrument temperatures - for each channel. Also, a table of nominal warm-cal count values for a range of nominal warm-cal target temperatures should be generated. The on-orbit analysis consists of a) comparing warm-cal counts with T/V values for the corresponding combination of temperatures and b) using the orbital variation of warm-cal counts due to variation in instrument temperatures (i.e. minus the estimated variation due to target temperature variation) to estimate the gain and its sensitivity to instrument temperatures and compare with T/V values.

2.6 Radiometric Sensitivity

The purpose of this test is to evaluate the radiometer sensitivity (NEΔT). This test will be performed with the instrument in full operational scan mode. Radiometric data provided in the Science data packets (APID=210_{16}) will be processed to derive system gain and NEΔT for all 22 channels. In addition to NEΔT, the receiver noise temperature and noise figure should be determined for each channel and compared with those derived from T/V data.

One simple methodology for the calculation of receiver noise temperature and noise figure, yet there are other ways as well, could be: Consider 100 temperature-normalized (as opposed to calibrated) observations of the internal target, fit a third-order polynomial, calculate the standard deviation of the difference between the observed brightness temperatures and those from the polynomial fit, multiply by the square-root of the product of effective bandwidth and integration time and subtract the average (over the 100 observations) of the physical temperature of the internal target.

The equations to determine Gain and NEΔT are as follows:

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$$NE\Delta T = \sqrt{\frac{1}{n_{sc}} \sum_{i=1}^{n_{sc}} SD_i^2}$$

Where: $$\mathrm{SD}_{\mathrm{i}}^2 = \frac{G_i^2}{N_s} \sum_{j=1}^{N_s} (C_{ij} - \overline{C_i})^2 \ ,$$

And: $$\overline{\mathbf{C_i}} = \frac{1}{\mathrm{N_s}} \sum_{\mathrm{j=1}}^{\mathrm{N_s}} \mathrm{C_{ij}} \ ,$$

And: $$\mathrm{G_i} = \frac{T_{hi} - T_{ci}}{M_i - N_i}$$

where
- i = scan index
- j = sample index
- n_{sc} = number of scans (100)
- N_s = number of samples per scan (4)
- C_{ij} = Hot Target counts for given scan and sample within scan
- T_{hi} = Physical temperature of the warm load derived from the PRT data in the Hot Cal Packet (APID=212_{16})
- T_{ci} = Physical temperature of the cold calibration
- M_i = Average of the radiometric readings in counts in the Science Packet (APID=210_{16}) viewing the warm load, beam positions 101-104 (4 samples per scan, for 8 scans)
- N_i = Average of the radiometric readings in counts Science Packet (APID=210_{16}) viewing the cold calibration sector, beam positions 97-100 (4 samples per scan, for 8 scans).

The results shall be trended during the full stabilization (the orbit-to-orbit variation of all four receiver shelf PRT readings is less than 2° C) time interval. The NEΔT requirements are shown in Table 2-1.

Table 2-1 Sensitivity NEΔT Requirements at 300 K, CP=5 C

Channel	Frequency (GHz)	3dB BW (deg)	Req. NEΔT (K)
1	**23.8**	**5.2**	0.50
2	**31.4**	**5.2**	0.60
3	**50.3**	**2.2**	0.70
4	**51.76**	**2.2**	0.50
5	**52.8**	**2.2**	0.50
6	**53.596+/-0.115**	**2.2**	0.50
7	**54.40**	**2.2**	0.50
8	**54.94**	**2.2**	0.50
9	**55.50**	**2.2**	0.50
10	**57.290344**	**2.2**	0.75
11	**57.290344+/-0.217**	**2.2**	1.00
12	**57.290344+/-0.3222+/-0.048**	**2.2**	1.00
13	**57.290344 +/-0.3222+/-0.022**	**2.2**	1.50
14	**57.290344 +/-0.3222+/-0.010**	**2.2**	2.20
15	**57.290344 +/-0.3222+/-0.0045**	**2.2**	3.60
16	**89.45+/-2.45[1]**	**2.2**	0.30
17	**165.5+/-1.5[1]**	**1.1**	0.60
18	**183.31+/-7**	**1.1**	0.80
19	**183.31+/-4.5**	**1.1**	0.80
20	**183.31+/-3**	**1.1**	0.80
21	**183.31+/-1.8**	**1.1**	0.80
22	**183.31+/-1**	**1.1**	0.90

NOTE: 1 Maximum allowable bandwidth

2.7 Functional Check-out

This test begins after ATMS is activated and fully functional. The test set will consist of 12 minutes of radiometric and H&S data taken while staring continuously (i.e., in diagnostic mode 148 radiometric samples per 8/3 second) at the internal (warm) and cold space targets alternately in 40-second steps. Namely, the total staring time for internal and cold target would be 6 minutes (135 scans), respectively.

The 2048-point FFT will be computed for each 40-second staring data, and this will be used to characterize the receiver 1/f noise. These data will be compared with ATMS T/V data. The analysis will focus on the gain, offset, NEDT, and 1/f characteristics.

Note that the above 12 minutes stare test should be repeated monthly for first six months after launch and whenever there is a chance (e.g., no science data collection times) afterwards for trending purpose.

2.8 Dwell Test

Set ATMS in diagnostic/point-and-stare mode for 5 minutes with continuous sampling enabled at the on-board calibration target (OBCT) position and optimal cold space view, respectively. Generate a time series of 16,384 data points separated by 0.018 seconds. Calculate the noise power spectrum, comparing it with T/V tests. NPP science team would assist in performing full statistical analysis of the sensor performance. The dwell data series should also be used to compute the average and standard deviation of warm-cal counts over N points, where N ranges from 1 to the length of the series. The purpose is to determine the N where the standard deviation is minimum and compare that with the power spectrum analysis. Any difference should be reconciled and the result used to optimize the calibration algorithm (i.e. update the calibration parameters).

2.9 Lunar Contamination in Space View

This task will serve as a check of lunar appearance predictions. To prevent the SV from the worst lunar contamination, we can change the SV sector (scan profile) in advance of predicted lunar contamination.
Note that switching between different scan profiles back and forth requires each scan profile being characterized properly over a period of time (e.g., a week). This could be a good test for processing lunar contamination. Moreover, switching between different scan profiles will happen only in the first 90 days post launch. This would help us to determine the characteristics of each scan profiles in dealing with lunar contamination.

Based on the current experiences with AMSU-B, when the Moon appears in the (optimal) SV sector, only 2 out of 4 pixels would be contaminated. For ATMS, at least one to three clean SV pixels are still good for regular science calibrations. This is an important opportunity to verify this issue (in terms of on-orbit operations and the SDR processing) and to verify if we don't need to apply software fix for the lunar contaminations.

Specifically, either with the optimal SV sector or with the less contaminated SV sector, the contamination will be measured for each space view and will be ignored if above some threshold. This approach preserves contaminated observations for which noise pushes data below threshold. An alternative is to know the beam pointing to better than (say) 0.5 degrees and eliminate space calibration views predicted to be contaminated. All calibration data could be preserved to determine, perhaps weekly or seasonally, the biases that result from this strategy so that we might continually update the calibration algorithm. The current SDR algorithm implementation uses the "alternative" method described above. It calculates the lunar contamination for each SV pixel based on the Moon position and the beam pointing information. The pixel is ignored if the predicted contamination is above a tunable threshold. The SDR calibration will proceed to use only "good" pixels which have predicted contamination below the threshold.

During early orbit we need to compare values from each of the space views to see if there are any side lobe differences that need to be accounted for in the ground code. We would expect that the C3 (Command, Control, Communications) system is responsible for calculating occurrences of the moon going through the space view and command the instrument to a space view collection that will not (or least) be contaminated in that orbital pass. The ground software needs to look at the space view selection to see if an adjustment is necessary for differences between space views.

2.10 NPP Roll Maneuver 1 – Cross Track Scan Check

All proposed spacecraft maneuvers are under study. Were this maneuver to occur, the following description would apply:
The goal of this maneuver is to characterize the cross-track scan bias dependence and determine at least part of any asymmetries that may exist. The roll maneuver involves moving the ATMS full-scan field of regard completely off the Earth and enables ATMS to collect radiometric data while looking at deep space and to compare those results with the instrument's cold reference. This maneuver enables a characterization of any side-lobe contamination in the ATMS.
The antenna pattern measurements for ATMS are imperfect (near G band they are substantially imperfect), and we don't know the impact of the NPP spacecraft structure on the antenna patterns. Therefore, further characterization of antenna pattern characteristics using on-orbit testing is essential.
Angle-dependent brightness temperature biases introduced by antenna sidelobes pose the highest risk to ATMS mission success with respect to climate studies for which data records with long-term accuracies approaching tenths of a degree Kelvin are desired. The tasks outlined in NPP maneuvers are expected to provide direct measurements of

integrated antenna sidelobe levels with accuracies substantially greater than those of the pre-launch antenna pattern measurements and will therefore lower the risk of CDR degradation due to antenna sidelobe effects.

2.11 NPP Roll Maneuver 2 – Imaging of Earth's Limb

All proposed spacecraft maneuvers are under study. Were this maneuver to occur, the following description would apply:
In this maneuver, the spacecraft and, by inference, the ATMS field of view is rolled to enable ATMS to scan down the Earth's limb. This enables a characterization of any side-lobe contamination in the ATMS.
The sidelobes of the innermost beams would not be tested here because their main beams would not leave the earth. Not being able to scan further in this direction forces us to assume symmetry in certain untested antenna parameters, but how serious this is will probably not be fully known until the experiments are performed.

2.12 NPP Pitch Maneuver

All proposed spacecraft maneuvers are under study. Were this maneuver to occur, the following description would apply:
In this maneuver, the spacecraft is pitched completely off the Earth to enable ATMS to acquire full scans of deep space, permitting the uniformity of the ATMS field of view to be characterized. When the earth's disk lies totally outside the beams and their larger sidelobes, then there should be good sensitivity to any anomalies introduced by obstacles near the spacecraft itself. This maneuver will also allow us to establish the baseline radiometer output (counts) for pure cold space. A pitch maneuver (35 min) would yield good sidelobe information fore and aft, but less for left and right sidelobe levels.

2.13 Functional Test after Roll/Pitch Maneuver

Repeat the same procedures as those in Sec. 2.7.

2.14 ATMS Geolocation in Stare Mode

The nadir stare mode is a very important early on-orbit checkout test, since it is by far the quickest and most accurate way of determining pitch and roll pointing in a short time (i.e. without having to wait to accumulate a large amount of data sufficient to form a high fidelity surface image). This test is described in the paper on co-alignment of the AIRS system (IEEE TGRS, vol 41, 343-351, 2003) – see the last section. The method was developed after the Aqua launch to verify the pointing of both AMSU-A and HSB, and the method works very well and is very accurate. It is necessary for ATMS to stay in stare mode for 24 – 48 hours, to ensure that a sufficient number of unobscured coastline crossings with suitable crossing geometry can be obtained.
In the stare mode, ATMS geolocation accuracy is obtained in two steps: (1) Use perpendicular coastline cross to calculate the along-track accuracy. (2) Use the oblique cross case to calculate the cross-track accuracy. Moreover, the FOV and antenna beam pointing accuracy are also derived.
The stare mode analysis will determine any pitch and roll offsets that need to be applied to the geolocation processing and used routinely thereafter.
Yaw offsets can be determined either by (a) going into swath-edge stare mode for a while (if that is possible), or (b) accumulating enough data to form high fidelity coastal images that can then be used to determine offsets between the observations and a map. The latter method can be used routinely, to monitor pointing during the mission, but it takes a lot of data and rather sophisticated analysis.

2.15 ATMS Warm Load Analysis

This test is partly a verification of the expected best spacecraft interface (cold) plate temperature. It should be made part of on-orbit performance verification tests. Determine the relationship between the warm load temperature and ATMS spacecraft interface (cold) plate temperature and that between the warm load and the shelf (or MUX) temperatures. Average the 4 warm load view measurements for each scan. Tabulate and plot the averaged warm load measurements against cold plate and shelf (or MUX) temperature data, scan by scan, for a 24-hour period. Compare these results with the ground test data. If there are no issues, we would only need to use nominal data to perform this analysis.

Since the on-orbit thermal environment will be different vs. T/V, if there is a significant discrepancy between T/V performance test results and flight test data, and/or if thermal gradients are too large, then a calibration correction may be needed. (Analyze PRT data with this test). Moreover, if the difference versus T/V is significant, we would need to make on-orbit performance measurement with ATMS stabilized at each cold plate temperature, in order to find out which temperature works best. In this case, analyze also the counts and temperature of cold space for optimal space view position versus different cold plate temperatures. Note that changing of the interface plate temperature also involves waiting for ATMS internal temperatures to settle to new equilibrium values, and running performance evaluations at the new cold plate temperature(s) & may have implications to s/c operations.

2.16 NPP Roll Maneuver 3 – Imaging of Moon

All proposed spacecraft maneuvers are under study. Were this maneuver to occur, the following description would apply:
Lunar views may also be used to determine the extent and magnitude of the sidelobe response of both low and high frequency ATMS channels. When the Moon appears in the ATMS SV sector we perform this maneuver by scanning across the Moon with EV pixels. We could examine the scan contaminations with respect to different view angles. Note that this maneuver would be performed if it is required for other NPP sensors.

2.17 ATMS Radiometric Environmental Characterization

The purpose of this task is to characterize the radiometric contributions originating outside the standard scan profile, including, for example, the angles between the earth limbs and the spacecraft. This exercise can also be performed when the moon is near the cold space views so that the angular effect on each channel can be characterized.

2.18 Nonlinearity Correction and Validation Plan

The nonlinearity correction lookup table resulting from the PFM T/V measurements will be derived. On-orbit, without the benefit of known calibration sources at intermediate brightness temperatures (such as were available during T/V testing), it is not possible to directly measure the nonlinearity. But, the nonlinearity correction is a function of the physical temperature of the detectors. So, on-orbit, we will rely on temperature readings from temperature sensors located near the detectors to determine the correction values to apply.

The correspondence between these temperature sensor readings and detector nonlinearity will come from the T/V test results. And while the on-orbit correspondence is expected to be different, we do not expect dramatic differences. After the instrument has reached a steady operational state on -orbit, a new on-orbit correspondence must be derived based on several orbits' worth of internal temperature readings, and running NG's and/or NASA's thermal model(s) of the instrument to better understand the appropriate weighting of sensor readings.

Depending on the magnitude of the estimated nonlinearity and it's rate of change, a decision can be made regarding how often the correction value needs to be updated. This has potential implications for climate data records.

3. COMPREHENSIVE PERFORMANCE EVALUATION

3.1 ATMS RFI Check

Determine ATMS RFI susceptibility. Any change in the RF environment will affect the RDR data if the sensor is susceptible to RF interference. Two types of RFI can be investigated. One is RFI from onboard transmitters or instruments and the other is RFI from ground sources. We need to investigate the radiometric count difference at the space and OBCT (OnBoard Calibration Target) views before and after an RF device or instrument is turned on. A big jump in radiometric counts indicates ATMS may be susceptible to RFI at that particular channel. For ground based RFI sources, we can only record the source locations for further reference. The onboard instruments will be CrIS, OMPS, and VIIRS. This test may be covered during the BATC Satellite I&T campaign with the Flight sensors when they do a self compatibility test.

A carefully sequenced power-up of the various on-board instruments would be valuable for locating local (on board) sources of potential RFI. Depending on the flexibility of the in-flight software there may have some means for mitigating local RFI.

The identification of RFI from ground sources requires the instrument to be operated in normal imaging mode for at least several (ideally at least several dozen) overpasses of every major continental area, along with a statistical analysis of this data that accounts for expected temperature and moisture variations. SDRs are need for such an analysis. Based on current market penetration of automobile collision avoidance radars using the 23.6-24.0 GHz band it seems likely that some RFI will be seen by ATMS. Unfortunately, not much can be done to compensate for this type of RFI post launch since it is highly variable.

The post-launch RFI identification procedure could include at least one follow-on airborne survey of the general area(s) of RFI-contaminated pixels so as to unambiguously determine the source(s) of interference. Without such source determination it may be impossible to mitigate if the transmissions are illegal. Also, we would perform a detailed study of atmospheric-compensated imagery with the goal of characterizing the statistics of the SDRs on a spatial basis, and particularly comparing such statistics between populated and unpopulated areas.

3.2 ATMS RFI Correction (if needed)

This test would be needed if RFI from onboard sources is detected. During the RFI check, if there is RFI from an onboard source, then a RFI correction factor should be derived. To check the RFI from on board transmitter, first we have to identify the RFI source. Then we check the radiometric counts before and after each transmitter is turned on. The temporal stability of any correction factor would need to be determined by examining its value during many orbits over enough time that all normal operating conditions of the offending source are experienced by ATMS.

3.3 ATMS Geolocation Check

Determine ATMS geolocation and navigation accuracy. From the window channels, ATMS maps geographical features, i.e., an island, lake or coastline. By comparing the position of known geographical features in the image with higher resolution ground truth (e.g., Landsat data), the ATMS geolocation accuracy can be determined. Plan to fly the NPP over a long coast line and to collect the scene brightness data. From the geolocation data and brightness temperature, we can determine the ATMS geolocation accuracy. The navigation accuracy will be derived by convolving land-sea masks with ATMS brightness temperature images. By varying the spatial position of the footprints and using knowledge of the sea surface temperature and homogeneous land temperature near coast line, the navigation accuracy can be determined. Note that for the non-window channels, 50 – 58 GHz, we would depend on those derived either from the pre-launch tests and/or from NPP Roll Maneuver 2 – Imaging of Moon.

3.4 ATMS Ascending/Descending Brightness Temperature Comparison

Determine pointing, navigation, and asymmetry errors. Global SDR brightness temperatures will be binned and averaged in 0.5 deg lat-lon boxes separately for ascending and descending nodes. These values will then be differenced. Any systematic pointing or navigation errors will be revealed by shadows on opposite sides of continental coastlines. Perhaps we could find the geolocation differences during day/night measurements. This could be used as a sanity check!

3.5 ATMS RDR Gross Anomaly Identification

Identification of radiometric outliers using simple statistical tools (e.g., histograms and scatterplots). Examples of sensor anomalies that would result in statistical outliers in the radiometric count data include RFI and A/D converter malfunction. Two problems that have been encountered on previous operational microwave sounders are RFI and A/D malfunction ("stuck bits"). These problems can escape detection during pre-launch testing because the on-orbit radiometric environment, as well as the sensor hardware characteristics, can be markedly different than that observed during pre-launch testing. In such cases, simple statistical tools can be used to quickly identify sensor anomalies.

The general idea is to amass a representative ensemble of radiometric data over a variety of scene types, and plot various statistical metrics derived from these data ensembles – examples include histograms of radiometric counts for each channel and scatterplots of the radiometric counts for channel X versus channel Y. These histograms and scatterplots can then be compared with those derived from model-generated data. Any gross discrepancies generally indicate a sensor anomaly.

Use 24 hours of radiometric (count) data and generate histograms and scatterplots as described above. Identify any gaps or discontinuities. The results of this task would be used to develop flags & action lists for operators—i.e., abnormal conditions to look for in the operational telemetry stream & instructions for operators when anomalies are detected. All engineering parameters should be analyzed for dependence on lat/lon, local time, sun angle, solar illumination of instrument surfaces.

3.6 ATMS Scan Uniformity Analysis and Scan Bias Analysis

Radiometer data will be collected for a long period of time and analyzed for potential field of view intrusion (by spacecraft or other sensors) and to characterize any asymmetry in the cross track scan pattern. To examine the brightness temperature imagery with high sensitivity requires averaging a relatively large data set of reasonably homogeneous scenes, e.g., rain free ocean or desert, to reduce the effects of geophysical fluctuations within the scene. To help determine the intrusion of the spacecraft, the spacecraft layout should be available for reference. Each ATMS channel will be analyzed for scan uniformity. Average and standard deviation will be computed. The ascending and descending pass will be analyzed separately. Plot the data as a function of scan position, channel by channel. The results derived from this analysis are expected to be comparable to those from NPP Roll Maneuver 1 – Cross Track Scan Check.

3.7 ATMS Resampling to AMSU FOV Verification

To verify that if the resampled ATMS data is comparable to AMSU. In polar regions, cloud-free ATMS data are convolved to AMSU fields of view using Backus-Gilbert method. The synthesized AMSU brightness temperatures derived from ATMS are then plotted against the AMSU brightness temperatures, and the mean and standard deviation of the difference is computed as function of scan angle. The AMSU brightness temperatures will also be compared to the "nearest neighbor" ATMS brightness temperature (i.e., no Backus-Gilbert processing). The Backus-Gilbert reprocessing of the ATMS footprints to AMSU footprints should yield lower RMS differences to actual AMSU data than the simple nearest-neighbor comparison. If this is not the case, the Backus-Gilbert coefficients should be reevaluated.

Note that it is possible that ATMS obs vs. calcs may differ from AMSU obs vs. calcs due to differences in the reflector/shroud geometries (i.e., they will have different sidelobe artifacts).

3.8 ATMS Parameter Trending

Trend NEΔT, telemetry, gain and offset through ATMS on-orbit lifetime. We would keep a time record of the various parameters for the duration of the ATMS lifetime. The key parameters are NEΔT, telemetry, gain, and offset. Compute and record the parameter values at various time scales (minutes to seasons). Also calculate down-track (cross track) versus along track differences (to identify RFI) as well as left-right scan asymmetry. Verify or update prelaunch calibration and dynamic range. Monitor on an orbital to seasonal time scale. Identify and understand correlation between instrument response function and spacecraft telemetry (such as temperature) or state (such as transmitter state). Verify RDR, including blackbody and cold space calibration analysis. Verify PRT to temperature conversion. Trend RDR engineering parameters (voltages, currents, temperatures).

3.9 ATMS Trending of Blackbody and Cold Space Count

Trend warm load counts vs. time and cold space view counts vs. time. To collect ATMS long term data for blackbody and cold space radiometric counts. From these long term data sets, perform statistical analysis and the trend for each data. From ATMS regular telemetry data, save the warm load counts, cold space view counts, and time of each data point that was collected. Save the results to special data files for analysis.

3.10 ATMS SDR Center Frequency Stability

Verify the frequency stability of the opaque 57.29-GHz channels. Long term trending of the brightness temperatures observed near 57.29 GHz as compared to synthesized 57.29-GHz brightness temperatures using CrIS stratospheric Q-branch channels near 667 cm^{-1}. The CrIS stratospheric channels will be regressed against the ATMS stratospheric channels (near 57.29 GHz) using model-data (for example, upper atmospheric data derived from MLS measurements which are then input to a radiative transfer model). Long-term drifts would most likely (but not necessarily) be due to a drift of the 57.29 GHz LO. If drifts are detected, more detailed analysis of both the CrIS and ATMS stratospheric channels would be undertaken by using high-fidelity ground truth (MLS, for example). Drifts exceeding 0.2K will be flagged. The stratospheric temperature should be horizontally homogeneous, and CrIS and ATMS should therefore agree very well (the difference in their viewing geometries is negligible due to the atmospheric homogeneity). We can use this fact as a simple check for any systematic drift between the two sensors.

3.11 ATMS Resampling to CrIS FOR Verification

Validation of ATMS resampling to CrIS FOR. Cloud-free ATMS data are convolved to CrIS Field Of Regard using the Backus-Gilbert method. CrIS brightness temperatures are used to predict ATMS brightness temperatures using regression analysis. The average brightness temperatures for the ATMS are then plotted against the CrIS and the mean and standard differences are computed as a function of scan angle. The weight of Backus-Gilbert convolution may need to be adjusted if substantial differences exist between the two instruments. From ATMS measured antenna patterns and CrIS FOR, the B-G coefficient will be derived. The effective ATMS FOR and Brightness temperature will be determined. The average of the ATMS brightness temperature will be plotted against the CrIS brightness temperature and the difference between should be less then 1 K.

Based on modeling predictions that without co-alignments between ATMS and CrIS, the resampled ATMS brightness temperatures would agree with CrIS FOR, with an error less than 0.1 K. We would compare also the BG-resampled ATMS to CrIS near coastline crossings, and for more stressing conditions (clouds, light precip, fronts).

3.12 ATMS High-altitude Aircraft Underflights

Compare high-resolution and high altitude aircraft brightness temperature images with those from coincident satellite overpasses. Campaigns will be designed to collect coincidental data under clear skies and non-precipitating cloudy conditions. This will be especially useful for cloud-clearing algorithms.

In general, the aircraft instrument must be capable of simulating (or exceeding where appropriate) the ATMS performance with respect to channels, scan geometry, footprint size, radiometric performance, and be capable of operating from high-altitude airborne platforms that will be available for underflights. Multiple aircraft instruments are available that meet these requirements.

3.13 ATMS SDR Comparison with Model Fields

ATMS brightness temperatures (both before and after resampling) will be compared to NCEP GDAS analyses. This would be general consistency check of ATMS brightness temperatures. We could also identify if there are any gross biases. There could be several explanations for substantial biases with respect to the GDAS data. The most likely are probably: 1) a channel swap (either in hardware or in software), and 2) LO drift.

3.14 ATMS NWP Radiance Validation

To assess ATMS global radiances and the Community Radiative Transfer Model for ATMS. ATMS radiances will be simulated using the NCEP/EMC Global Forecast System and a radiative transfer model. The simulated radiances will be compared with those observed on a global and regional basis. Statistics will be compared with microwave instruments on NOAA-15-18.

3.15 ATMS SDR Comparison with Radiosonde Observations (RAOBs)

Validate the calibration of ATMS. Cloud-screened ATMS SDRs collocated with dedicated RAOB launches will be compared, and any potential ATMS biases will be identified. Potential RTMs for this task are AER's OSS model, Rosenkranz's RTA, etc. We need dedicated Raobs (i.e. released to coincide with sat overpasses). Also need some with accurate water vapor sensors. We should set something up at the ARM/CART sites as we have done with AIRS.
Nominal frequency of radiosonde launches: two launches of two raobs at each of the three ARM sites (tropical, mid-latitude, and high-latitude) per day (total of 12 raobs launched per day).

We could possibly get by with less than 12 launches per day: For the tropical site we won't get two overpasses every day, and the weather doesn't change that fast, anyway. At the mid-latitude site, we could get two overpasses, and launch two sondes for each (by the way, double launches are for the purpose of using Dave Tobin's analysis method) although they didn't keep up that high an average for the AIRS validation effort. At a high-latitude site, we get frequent overpasses, so the normally scheduled radiosondes may be perfectly adequate (close enough to overpass times) if the budget is constrained.

The objective is to assemble a "golden set" of a few hundred matchups of RAOBS and CrIMSS FOR's in clear-air. This data set will be used to help validate the transmittance models and the SDR/EDR algorithm performance.

In addition to normal validation, dedicated raobs at ARM/CART sites will be used as climate reference data points in long term monitoring to determine trends and drifts in the observing system. They will also be used to determine empirical scan biases, as a backup to the orbit-maneuver method described in sec. 2.12. These applications are crucial to the climate mission, and it is extremely important to maintain regular launches of these dedicated radiosondes (i.e. where the launches are timed to coincide with satellite overpasses). In this context, "operational radiosondes" (which are launched at fixed UT times, typically 0Z and 12Z) are of low value and cannot be used as substitutes for dedicated launches of high quality radiosondes.

4. ABBREVIATIONS AND ACRONYMS

ADC	Analog-to-Digital Converter
APID	Application Process Identification
ATMS	Advanced Technology Microwave Sounder
C&T	Command and Telemetry
CBIT	Continuous Built-In Test
CrIS	Cross-track Infrared Sounder
EDR	Environmental Data Record
EMI	Electromagnetic Interference
FOV	Field of View
IBIT	Initiated Built-In Test
KAV	K-band, Ka-band, and V-band channels (channels 1-15)
MLI	Multi-Layer Insulation
NEΔT	Noise Equivalent Delta Temperature
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NPP	NPOESS Preparatory Project
PAT	Passive Analog Temperature telemetry
PRT	Platinum Resistance Temperature sensor
SAW	Surface Acoustic Wave filter
SDE	Scan Drive Electronics
SDM	Scan Drive Mechanism
SPA	Signal Processor Assembly
UIID	Unique Instrument Interface Document
WG	W-band and G-Band channels (channels 16-22)